

National Transportation Safety Board

Office of Research and Engineering

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SOUND SPECTRUM

Specialist's Study

September 11, 2024

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A. ACCIDENT

Location: Mooresville, North Carolina
Date: December 31, 2023
Time: 12:13 eastern standard time (EST)
Aircraft: Piper Aircraft PA46R-350T, N539MA

B. SOUND SPECTRUM SPECIALIST

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C. DETAILS OF THE INVESTIGATION

The NTSB received a video file from a camera located at a private residence about 380 feet from the accident aircraft's flight path and about 800 feet from the reported wreckage site. The video file was downloaded by non-NTSB personnel and forwarded to the NTSB for review.

The video had a timestamp overlay that indicated it started at 12:13:14 EST and ended at 12:15:17 EST on December 31, 2023. The timestamp overlay in the video was not validated with any external source and all times in this report are expressed as EST, from the timestamp overlay, or video elapsed time, which is the time elapsed since the start of the video.

Metadata indicated the video had 1920x1080 resolution, a frame rate of 20 fps, and recorded audio at a rate of 48kHz.

The accident aircraft was visible on the recording at 12:13:41 EST, traveling from right to left across the screen. When the aircraft was first visible, there were minor oscillations in roll and the propeller was rotating. About six seconds later, at 12:13:47, the aircraft started to bank to the right and lose altitude. The aircraft was no longer visible at 12:13:50 EST. At 12:13:53 EST, the aircraft's impact with terrain was audible.

Figure 1 is a Google Earth overview of the accident area. The location of the camera, Lake Norman Airpark, the ADS-B track of the accident aircraft including the final recorded data point, and the approximate location of the wreckage are shown. Note that the weather and lighting conditions in the Google Earth overview are not necessarily representative of the weather and lighting conditions at the time of the accident.



Figure 1. Google Earth overview of the flight path, location of the camera, Lake Norman Airpark, and the accident aircraft's wreckage. Red arrows along the flight path show the direction of travel.

1.0 Sound Spectrum Study

Audio from the video was evaluated to determine the operating speed of the aircraft's engine and/or propeller before the accident.

The accident aircraft was equipped with one Lycoming TIO-540-AE2A six-cylinder direct-drive turbocharged piston engine and a Hartzell three-bladed constant-speed propeller. The noise generated by the propeller for this type of engine is generally the strongest at the fundamental blade passage frequency (BPF).¹

For a three-bladed propeller, the expression relating engine RPM to the fundamental BPF is provided in equation 1:

$$RPM = BPF \left(\frac{\text{blades}}{\text{sec}} \right) * \frac{1}{3} \left(\frac{\text{rev}}{\text{blades}} \right) * 60 \left(\frac{\text{sec}}{\text{min}} \right) \quad \text{eq. 1}$$

The engine manufacturer's operator's manual stated that the engine's normal rated continuous power setting was 2500 RPM, which would be most evident at a BPF of 125Hz.²

A spectrogram was generated, as shown in Figure 2, showing the frequency content of the sound from the camera and how it changed over time from 12:13:40 EST to 12:13:56 EST (00:26 to 00:42 video elapsed time). The x-axis represents time in elapsed seconds of the video and the y-axis represents sound frequency in Hertz (Hz). The color represents sound intensity, with black being the lowest intensity sound and orange being the highest intensity.

Overall, the BPF signal-to-noise (SNR) ratio was low as there were two people in the foreground of the video speaking and playing outside. Additionally, there was a 120-125Hz band of noise present throughout the entirety of the recording. Nonetheless, there appeared to be visible lines of BPF, and its harmonics present in the spectrogram as annotated in Figure 2. Also note the gradual downward slope of the lines of BPF and harmonics as time passes, which suggests that the influence of the Doppler effect was present. Broadband noise consistent with the aircraft's impact with terrain was also visible starting at 12:13:53 EST (00:39 video elapsed time).

The emitting audio source of interest, the aircraft's propeller, was perpendicular to the camera at 12:13:45 to 12:13:46 EST (00:34 to 00:35 video elapsed time), thus,

¹ Smith, M. (1989). "Aircraft Noise." Cambridge University Press.

² Lycoming TIO-540-AE2A Series Operator's Manual (60297-27), 2nd Edition, November 2006.

the influence of the Doppler effect could be ignored.³ A Fast Fourier Transform (FFT) generated for this second, as shown in Figure 3, indicated a fundamental BPF of about 54.25Hz. Using equation 1, this fundamental frequency corresponds to an engine speed of about 1100 RPM during that time.

The aircraft manufacturer conducted a test flight using the same model aircraft as the accident aircraft to determine the RPM of the propeller when it was windmilling (i.e. idle engine power).⁴ The results from the flight test at different indicated airspeeds as low as 90 knots, which represents the aircraft's best power-off glide speed, are shown in Table 1 below.

Table 1. Windmilling (idle engine) propeller RPM settings.

Airspeed (knots)	Propeller RPM (RPM)
120	2500
110	2310
100	2010
90 (best power-off glide)	1730

To predict the propeller RPM at airspeeds lower than 90 knots, a linear regression was calculated for the test data. The least squares linear regression of the data in Table 1 is provided in equation 2:

$$\text{Propeller RPM} = 26.1 * \text{KIAS} - 603 \quad \text{eq. 2}$$

Although the airspeed of the aircraft before the accident was unknown, the groundspeed of the aircraft was derived using ADS-B returns and indicated that the aircraft was traveling at about 70 knots over ground for the final seconds as it traveled past the camera before it impacted terrain. Additionally, a weather observation facility located at Statesville Municipal Airport in Statesville, North Carolina, which was about 10 miles from the accident site, indicated that at the time of the accident, the wind was calm, and the barometric pressure was 30.07 inHg.

Using equation 2 and assuming that the unknown airspeed of the aircraft before impact with terrain was within 5 knots of the derived groundspeed given the weather conditions described above, the predicted propeller RPM for an airspeed of 65-75

³ The Doppler effect states that, for a source with constant emitted frequency, the measured frequency is higher than the emitted frequency as the source approaches the observer, identical as the source passes perpendicular to the observer, and lower as the source moves away from the observer.

⁴ The aircraft manufacturer noted the test flight was conducted with a Piper PA46-350P with the same model engine as the accident aircraft. Idle power glide propeller RPM was measured for a glide performed with the engine at power idle with mixture at full rich, and the engine at idle power with mixture at idle cutoff. The manufacturer stated there was no difference in the propeller RPM at different mixture settings.

knots is about 1100-1350 RPM, which is consistent with the RPM value calculated using the BPF in equation 1.

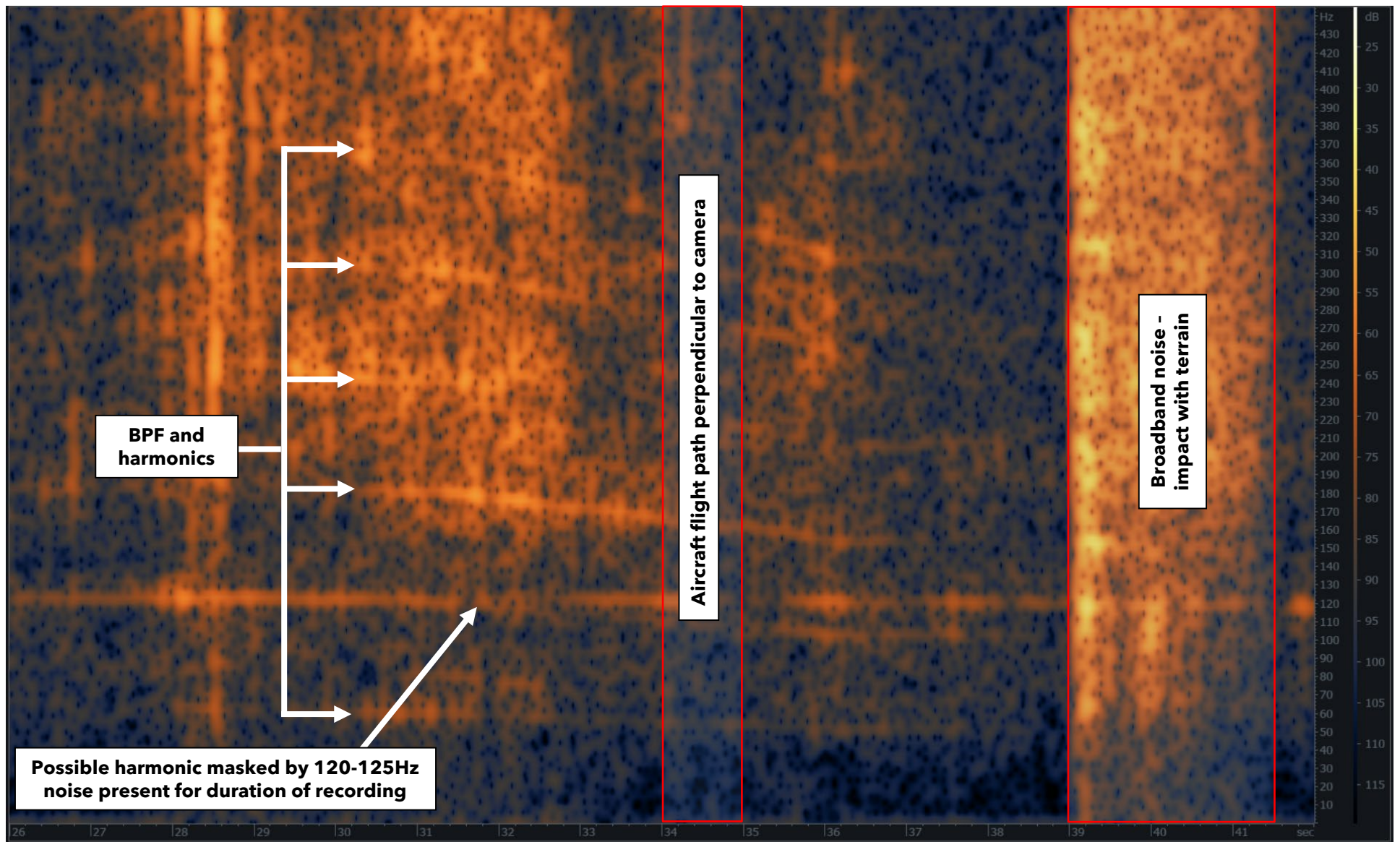


Figure 2. Spectrogram of audio from 12:13:40 EST to 12:13:56 EST (00:26 to 00:42 video elapsed time).

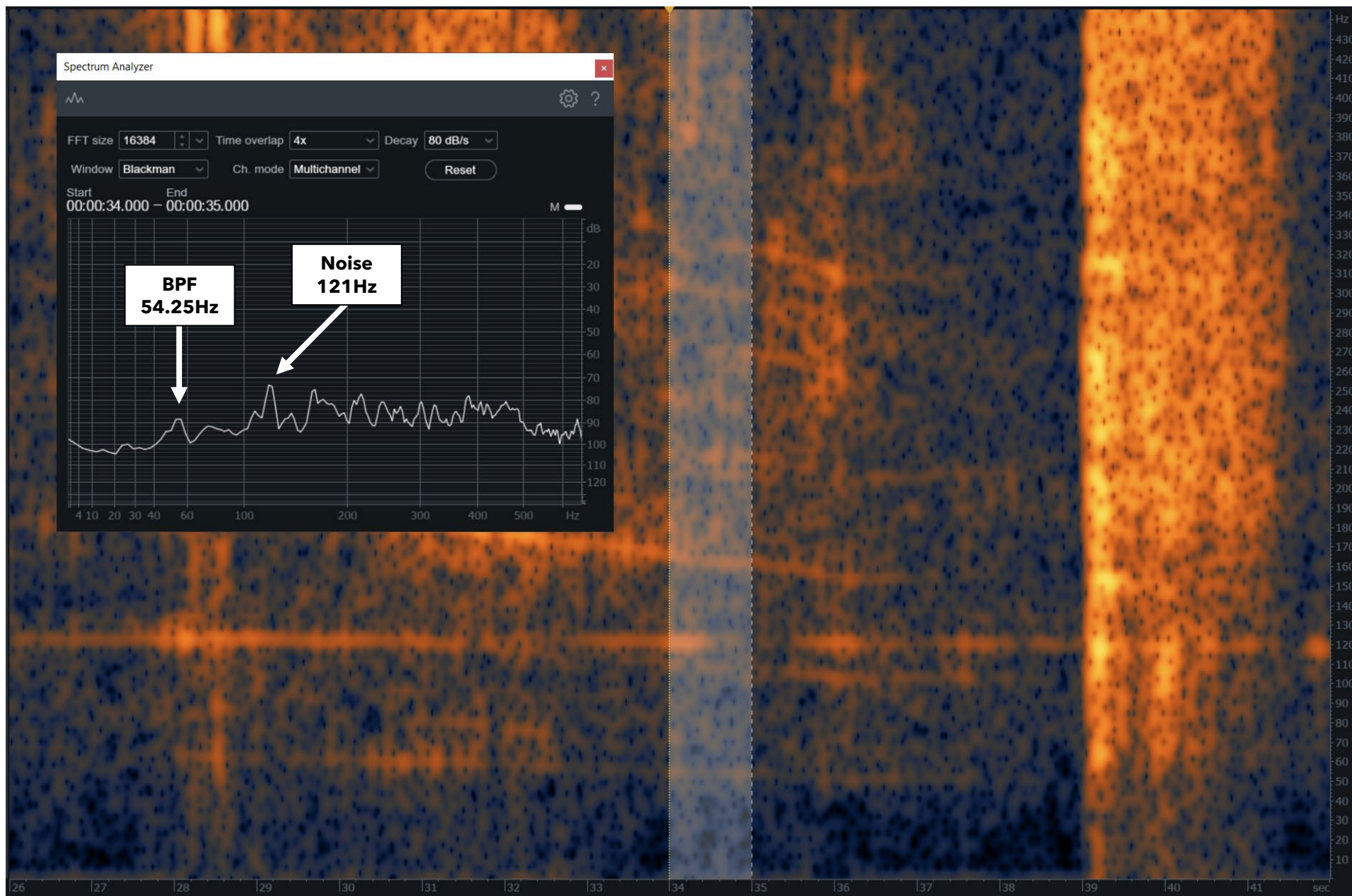


Figure 3. FFT of audio from 12:13:45 to 12:13:46 EST (00:34 to 00:35 video elapsed time).

1.1 Conclusion

The sound emitted by an aircraft that was captured on a camera at a private residence near the wreckage site was used for estimating the speed of the aircraft's engine prior to impact with terrain. The calculated engine RPM before the aircraft impacted terrain appeared to be consistent with the propeller windmilling at or near 1100 RPM, which is below the engine's published maximum continuous power setting of 2500 RPM.

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